

Flight Test & Recovery of Gun Launched Instrumented Projectiles using High-G On Board Recording Techniques

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Abstract— Researchers at the Weapons and Materials Research Directorate of ARL have recently completed experimental testing with a G-hardened gun launched miniature instrumentation package that fits within the projectile fuze cavity for obtaining realistic in-bore, deceleration and projectile impact data. This device consists of an accelerometer and a digital recorder that is designed for the reliable capture of ballistic data during projectile launch, flight and target impact. During recent flight test evaluation at the ARL, APG, projectiles containing this device were tested with a telemetry link as well as recovery and direct downloading of on board recorded data. For projectile impact studies both concrete and bunker targets were successfully engaged. This methodology of on board data recording has been shown to provide a reliable and high fidelity characterization of projectile in-bore and impact events critical for advanced munitions designers.

I. INTRODUCTION AND BACKGROUND

The U.S. Army is currently interested in a number of advanced munitions concepts ranging from small and medium caliber guided projectiles to large caliber long range projectiles having complex telemetry hardware, embedded inertial measurement units (IMUs), GPS capability, and sophisticated control and maneuver mechanisms [1-4]. Typically on board telemetry is utilized to provide measurements of the physical behavior of projectiles during launch and flight [5]. While the accuracy, ease of use and reliability of telemetry has been thoroughly verified for acquiring valuable engineering data, similarly high fidelity recording of sensor data directly on board projectiles has been demonstrated as a cost effective mechanism for T&E purposes. Of course an additional requirement for on board recording techniques is the ability to successfully recover the test projectile after the flight test is completed for downloading stored data. The remainder of this report is dedicated to a description of OBR hardware for smart munitions and ballistics R&D and illustrations of experimental data obtained from projectile flight tests which utilized this hardware.

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II. OBR SYSTEM DESCRIPTION AND CHARACTERISTICS

The in-bore recorder is a data encoder designed to capture events that happen while a projectile is in the bore of a gun tube and then play back that data over a telemetry link while the projectile is in flight. Alternatively, the system can be used as a stand alone OBR for direct storage of data on the projectile. However, without a telemetry link the ability to recover the projectile and recorder hardware is required to access the stored data. The recorder samples up to 8 analog data channels of a maximum aggregate rate of 833 kSamples/sec with 12 bit resolution. The memory is 128 kSamples deep for a maximum recording time of 157 mSec at the fastest sampling rate. Memory can be set aside to store pre-trigger data. The recorder is triggered by an on board acceleration switch or an external signal. Before and during the recording period, the encoder transmits live data from channel 1. This allows for time alignment of the in-bore data with externally recorded data such as a fire pulse. After the data are captured, the encoder then switches to transmitting the recorded data repeatedly until the end of the projectile's flight. Each repeat interval is 11 times as long as the recording period. Thus, if 100 ms of data was recorded, it would take 1.1 second of flight time to receive the data. All 8 channels are high impedance, 0 to 5 V inputs. The diameter of the board is 1.125", see Figure 1, and it has been used in rounds as small as 40mm. The recorder has survived acceleration loads as high as 100,000g. The OBR is designed to record data from standard accelerometers or other piezo-resistive sensors and the OBR can be powered from a lithium-ion battery pack. The system is designed for operation over the temperature range of -40 F to +145 F.

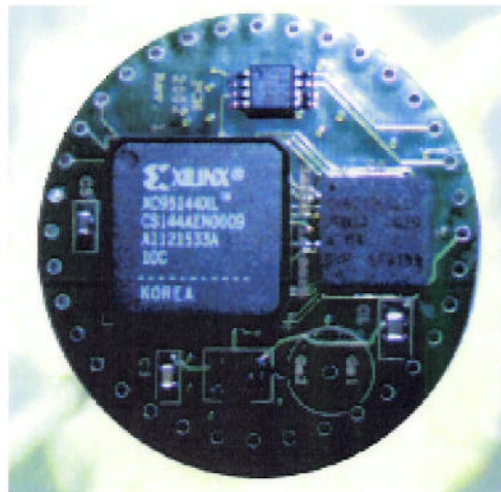


Fig. 1. Photograph of 1.125" miniature high-g on board recorder (OBR) for telemetry and soft recovery data downloading of on board projectile sensor data.

III. GROUND TEST AND FLIGHT TEST RESULTS

Prototype OBR units were first shock table tested at ARL. This was done with an MTS shock table up to the level of approximately 30,000-g's. After OBR units were shown to survive the shock table additional air-gun testing was carried out to ensure survivability up to 100,000-gs. Interior ballistic (IB) simulator projectiles were instrumented with shock qualified OBR units for the purpose of obtaining realistic in bore pressure and acceleration data. The simulator is typically used as a surrogate to match the interior ballistic performance of actual kinetic energy rounds during experiments involving test and evaluation. As shown in the drawing of Figure 2, the projectiles were drilled out in the front and rear sections to house the TDU telemetry instrumentation kit and pressure sensor, respectively. The tracer was removed from the fin section of the projectiles and a pressure sensor and steel insert were installed in its place. A hole was drilled through the entire body of the projectile extending from the fins to the front end for the purpose of allowing the pressure sensor wires to connect to the telemetry module. With this arrangement the projectiles were fired from an M256 tank cannon at the Aliant Tech Systems Proving Ground in Elk River, MN. The resulting accelerometer and projectile base pressure from a gun firing with the integrated OBR and telemetry hardware is given in the plot of Figure 3.

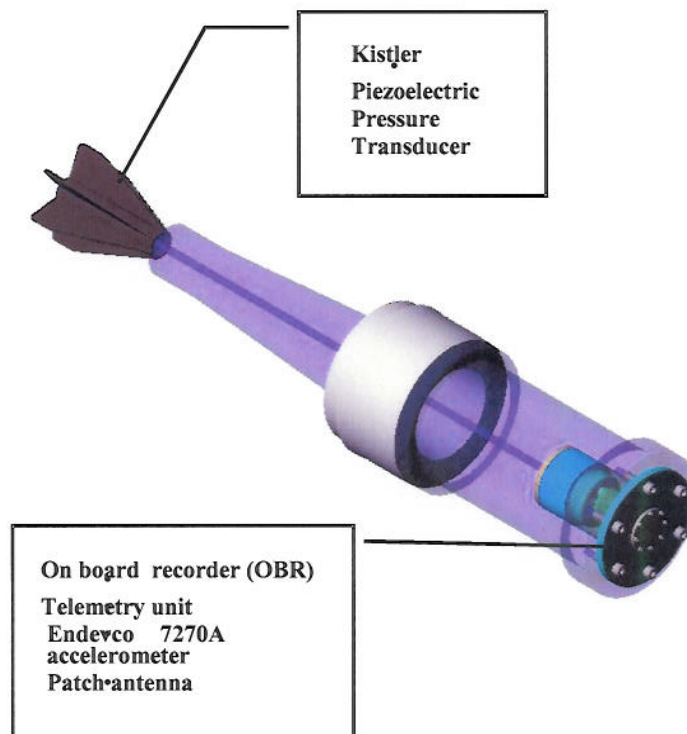


Fig. 2. Picture of telemetry instrumented IB simulator projectile showing the telemetry module on the front section with integral OBR and the location of the piezoelectric pressure for the base pressure measurement.

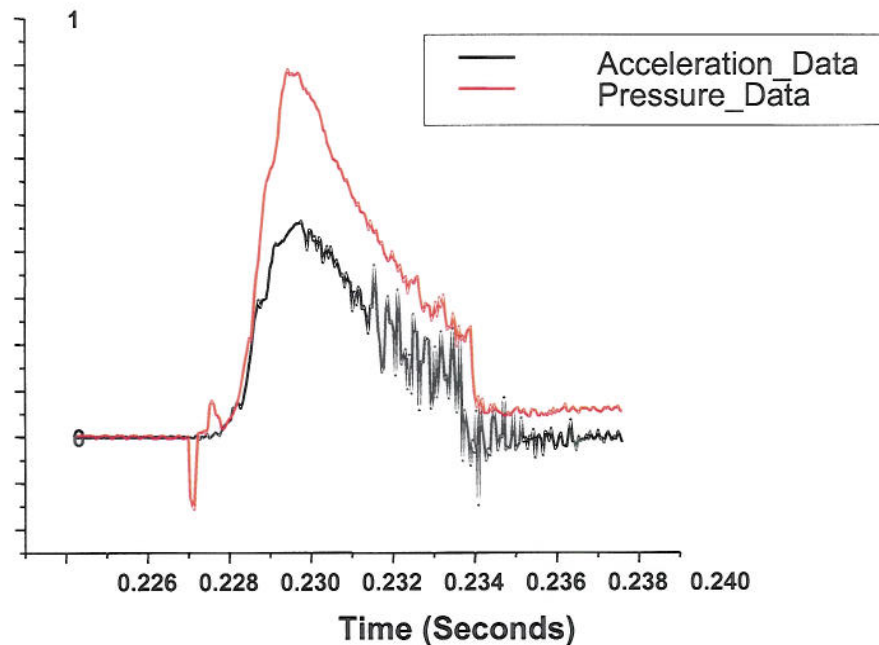


Fig. 3. Data (normalized) from instrumented IB simulator projectile with OBR and telemetry hardware to obtain in-bore projectile base pressure and axial acceleration as the round is launched from an M256 tank cannon.

Additional flight tests were conducted with OBR hardware and projectiles designed to breach bunkers. For these 120-mm projectile studies the OBR units were operated without a telemetry link, thus the requirement for projectile recovery was imperative. Following an experimental firing program, a fairly reliable range recovery technique was identified. The “soft” catch recovery system was used to successfully recover two projectiles and the resultant acceleration data from an Endevco 7270A high-g accelerometer were downloaded to a PC in the field moments after the gun firings. The data of Figure 4 are representative waveforms of on board acceleration as measured during the projectile launch and subsequent impact with the range break screen, bunker target and two sections of the mulch filled soft recovery system. The black curve is the raw data obtained directly from the recovered projectile while the red curve shows a filtered version of the same. For both tests the accelerometer and associated hardware successfully survived gun launch, impact deceleration event of approximately 7kgs’ and the projectile soft catch event.

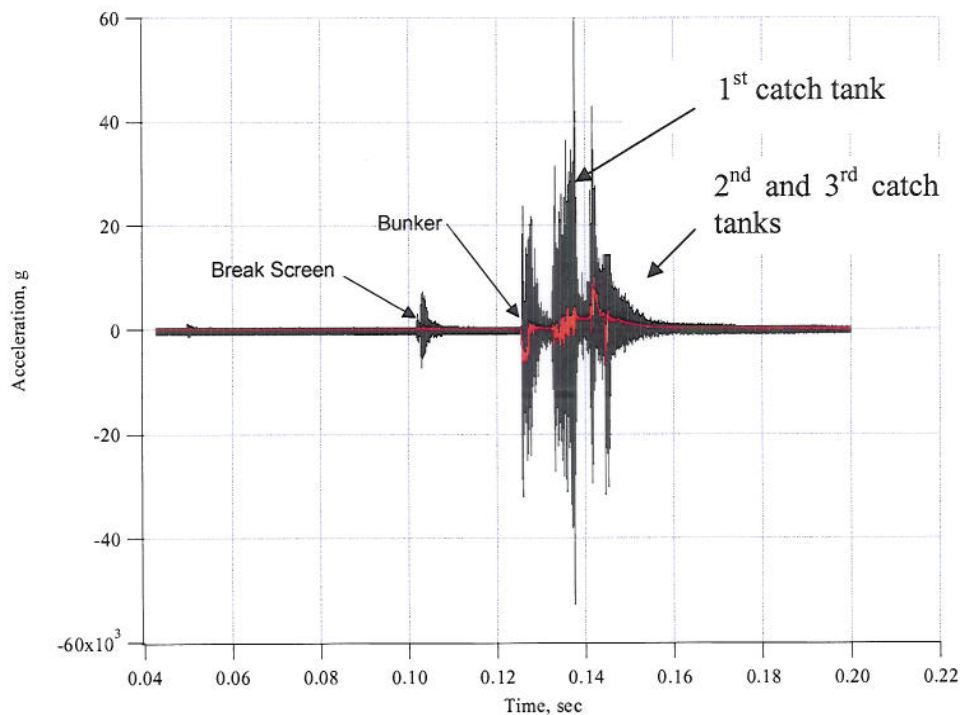


Fig. 4. Data from 120-mm round instrumented with OBR hardware for impact studies. The resultant accelerometer measurements from impact with the break screens, bunker target, and soft recovery system are illustrated.

IV. CONCLUSIONS

On board recorder (OBR) measurement techniques have been developed and demonstrated for gun launched projectile in-bore, in flight and impact studies. The methods and instrumentation developed have been shown through recent projectile flight testing at APG and Elk River to provide an effective and low cost approach for the continued development of advanced munitions technology. The flexibility of utilization with either telemetry links or within projectile soft recovery systems further validate the value of on board recording systems during test and evaluation of emerging weapons concepts.

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